

Nondestructive Evaluation of Spot Welds Using Acoustic and Thermographic Imaging Techniques

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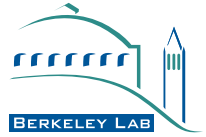
Overview

- Introduction
- Samples
- Thermographic Techniques
- Conclusion
- Ultrasonic Methods
- Conclusions

Introduction

- Online inspection of automotive structures
- Non contact sensors
 - * fast, robust, accurate and cost-effective
 - * suitable for online inspection
 - * real time diagnostic
- Analytical and numerical models

Samples

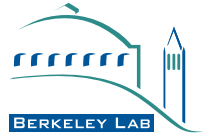


- Strips of galvanized steel
 - 5 welds plus 1 anchor weld
 - 9 reference strips for system calibration
 - Cold (no nugget pulled from sheet)
 - Undersized (nugget is too small)
 - Satisfactory (nugget / $4\sqrt{t}$)
 - Total of 30 sample strips with random weld quality

Pulsed Thermography

- 8-12 micron scanning camera
- Full frame rate 60Hz
- Line scan rate 1.8kHz
- Image size of strip ~ 760x80
- Short duration thermal pulse (3ms)
- Power limited by detector saturation
- Acquired 128 frames after pulse

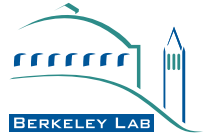
Signal analyses



Post-processing algorithms:

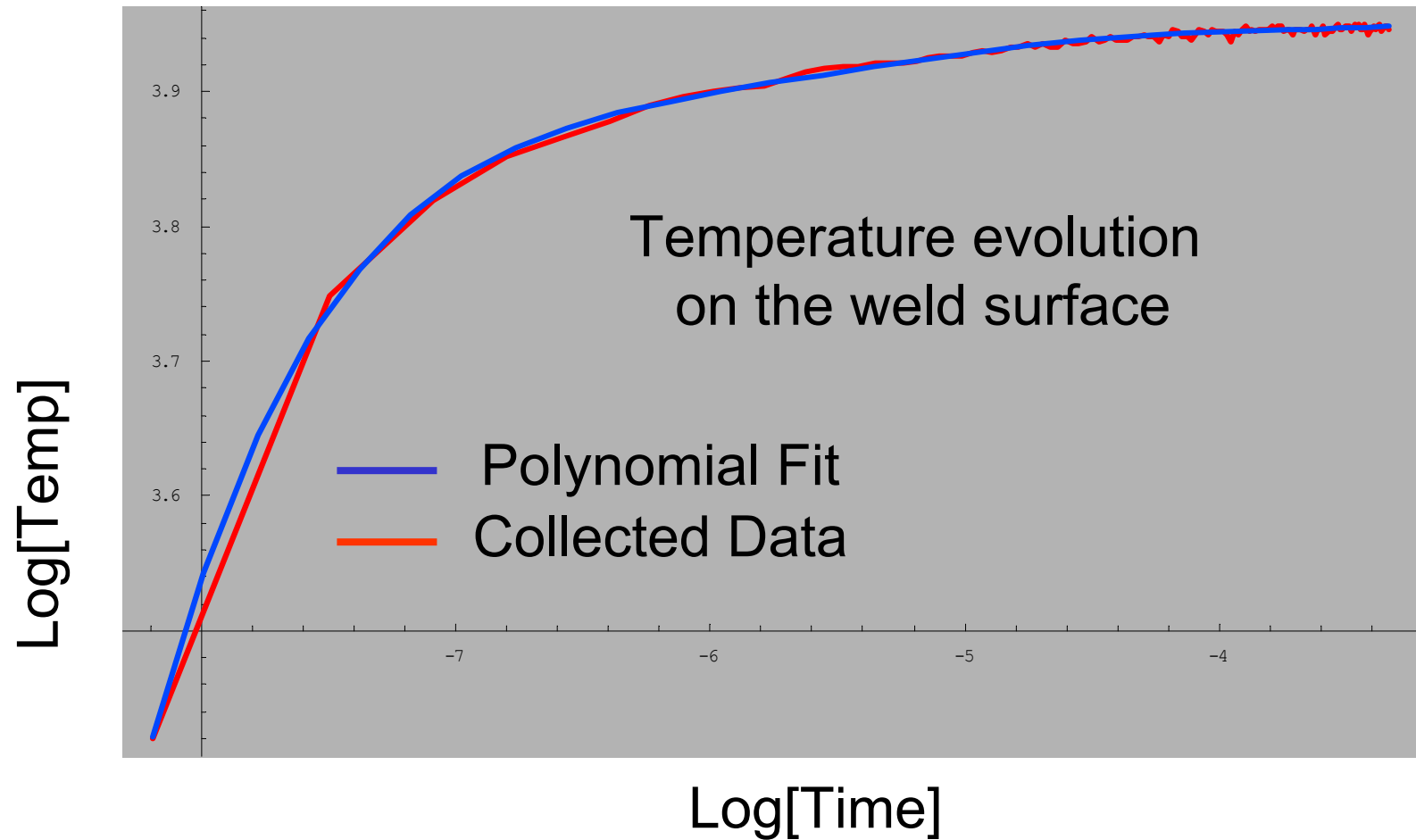
- Polynomial fit of log/log scale data
- Thermal diffusivity analyses
- Pulse phase analyses

Polynomial Fit

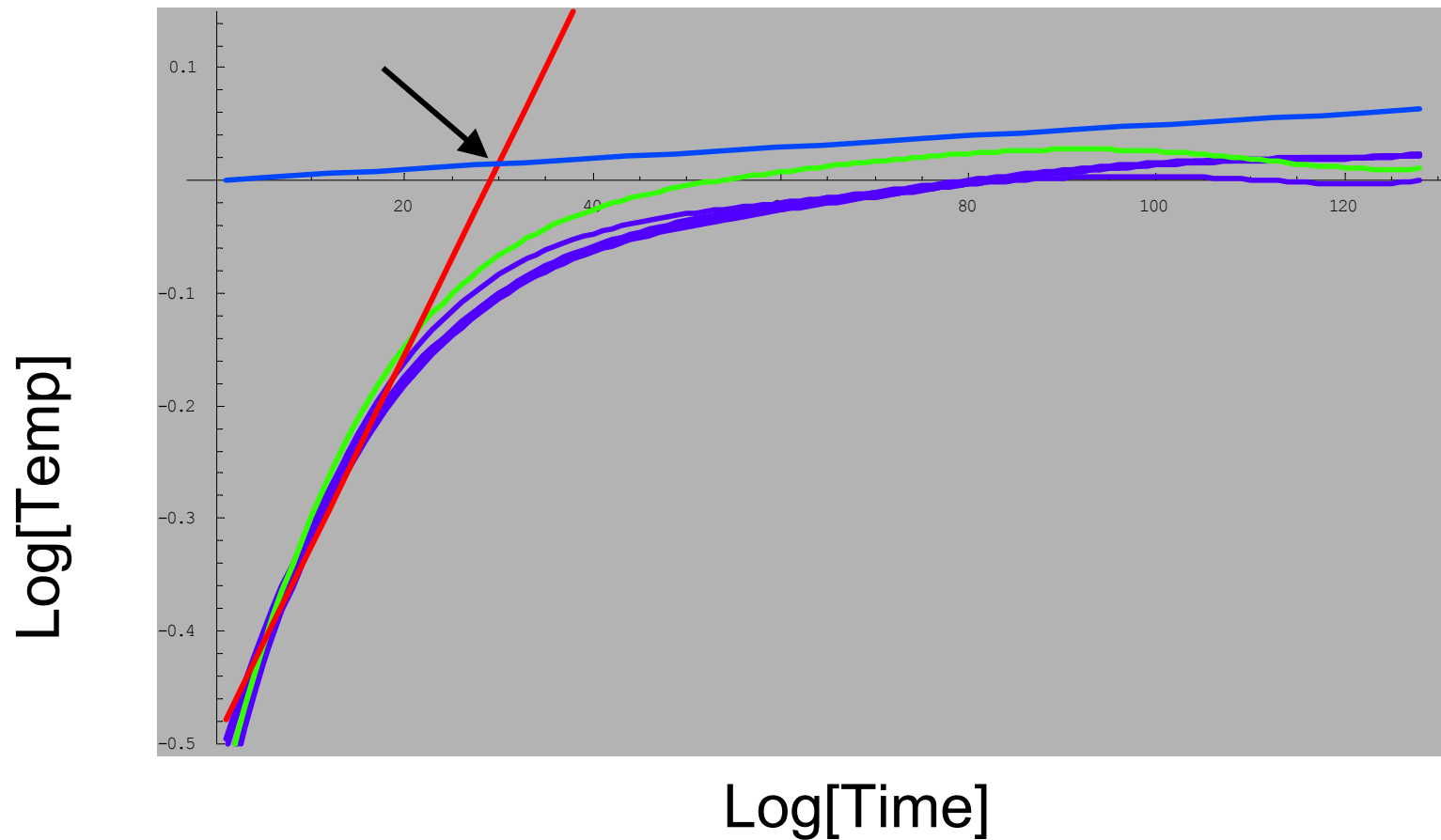
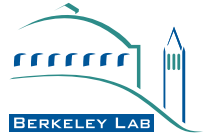


- Data is expressed with only 6 coefficients
- Dropping higher order terms provides smoothing without blurring
- Gradient can be determined analytically
- Scanner data can be corrected to remove acquisition delays

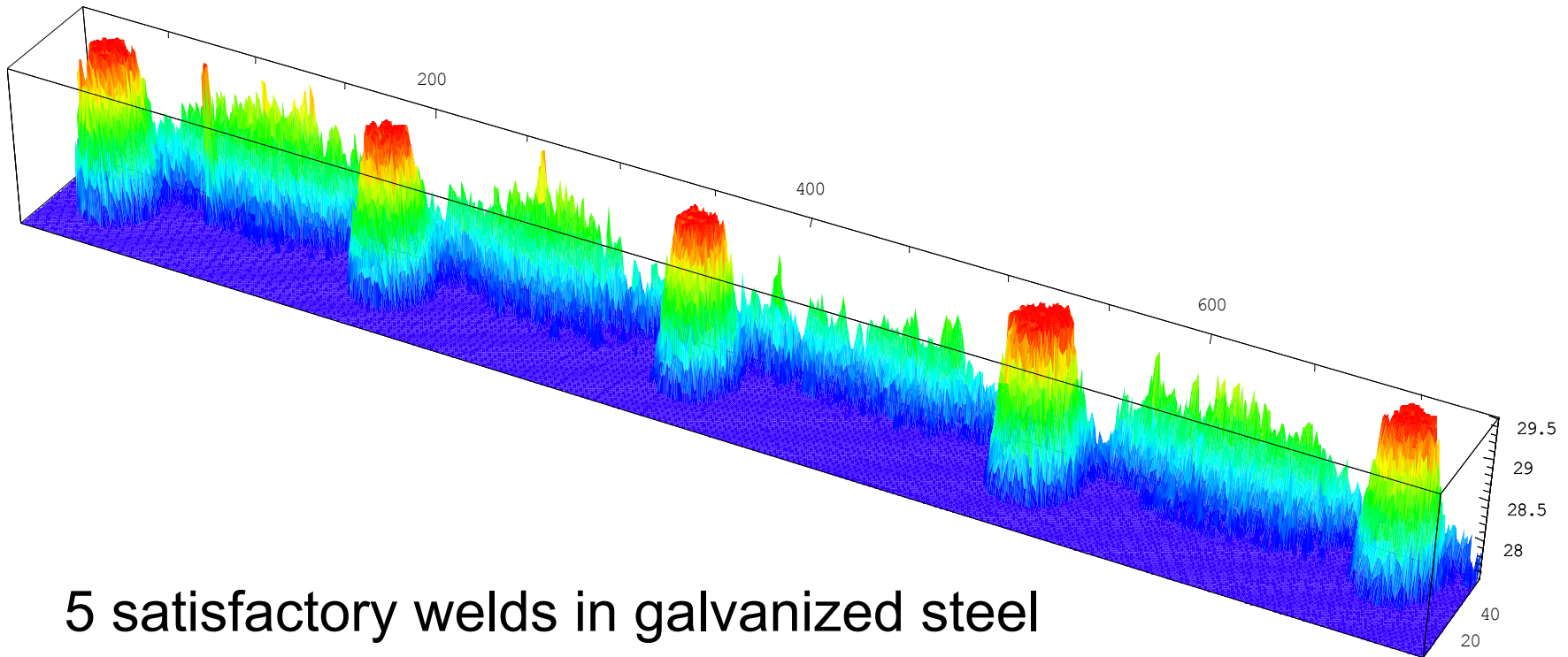
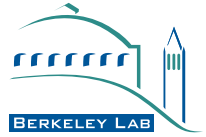
Polynomial Fit



Thermal Diffusivity

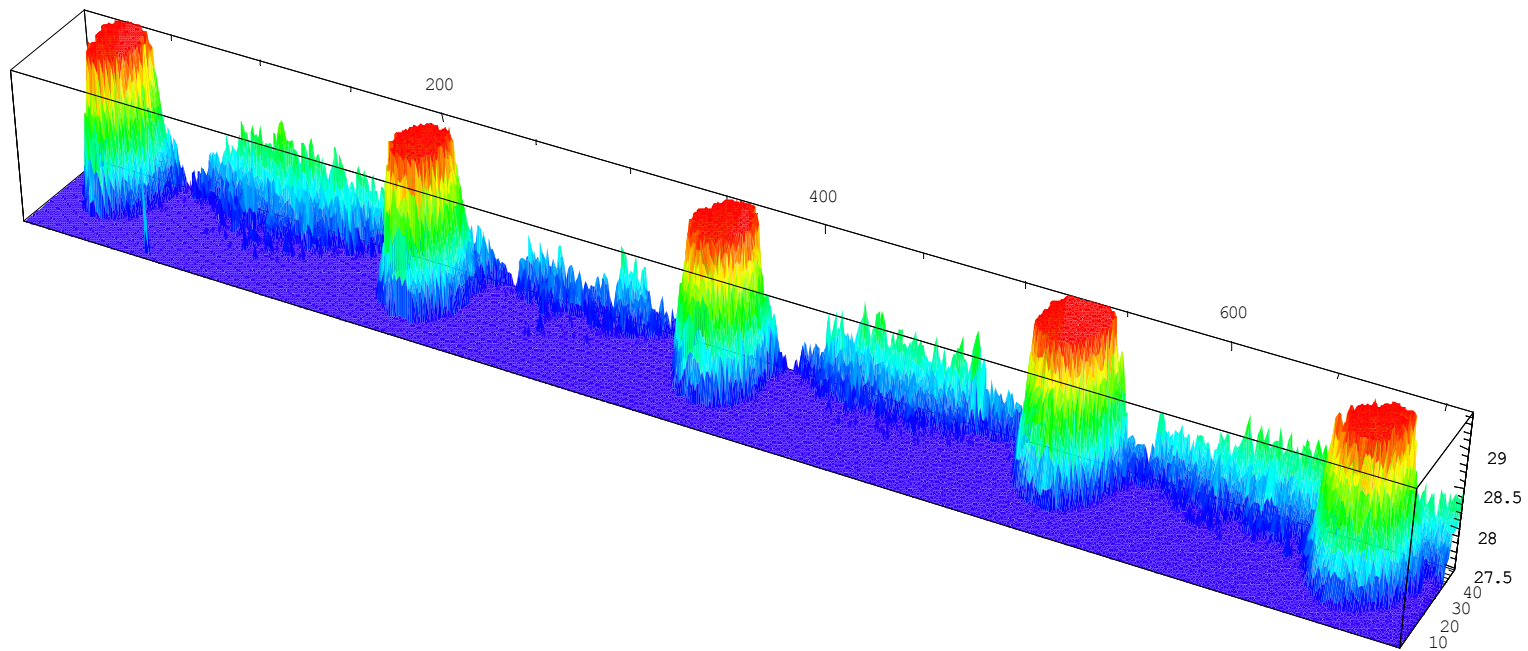


Thermal Diffusivity



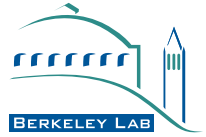
5 satisfactory welds in galvanized steel

Thermal Diffusivity



5 cold welds in galvanized steel

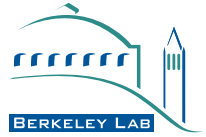
Pulse Phase Thermography



Pulse Phase Thermography (PPT)

- Provides good information at depth
- Compiles the time series into two frames
- Fast algorithm

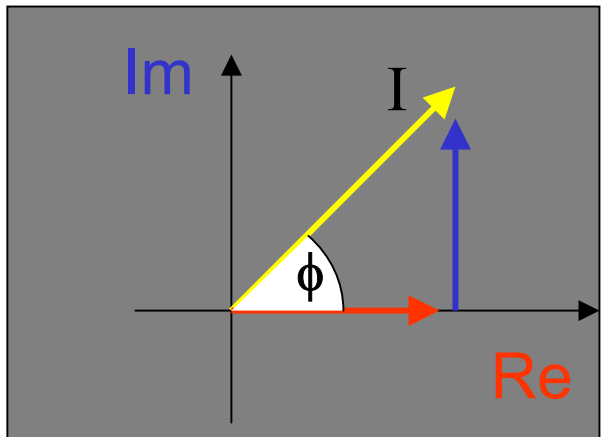
Pulse Phase Thermography



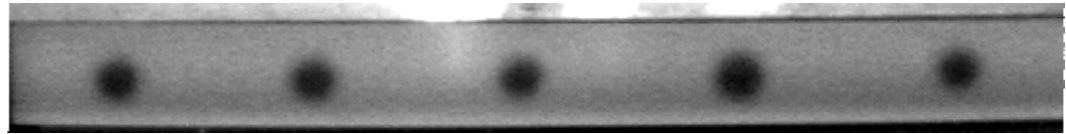
Data



FFT

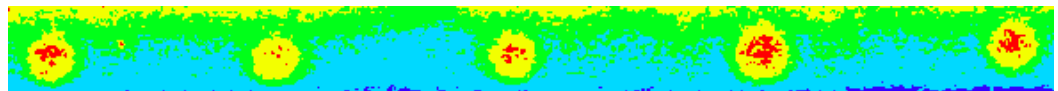


Raw IR data:



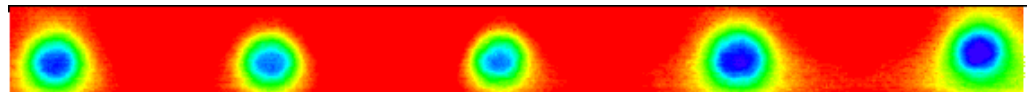
Maximum phase:

$$\phi(u) = \tan^{-1}(\text{Im}(u)/\text{Re}(u))$$

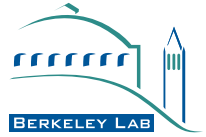


Maximum Amplitude:

$$I(u) = \sqrt{\text{Im}(u)^2 + \text{Re}(u)^2}$$

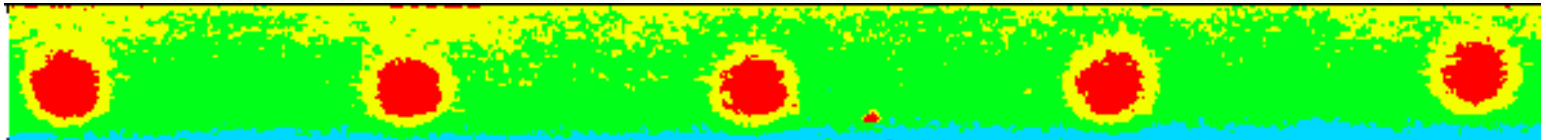


Pulse Phase Thermography

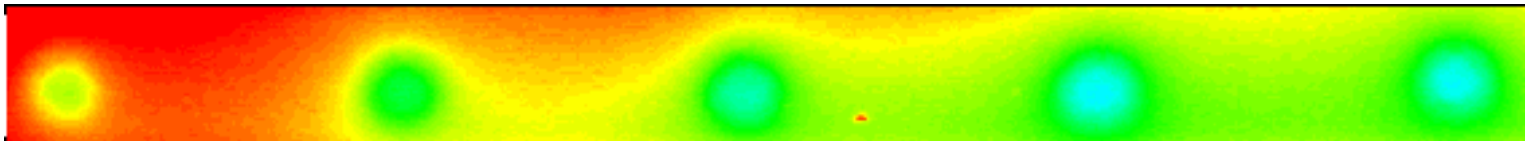


5 satisfactory welds

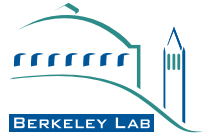
PPT maximum phase:



PPT maximum amplitude:

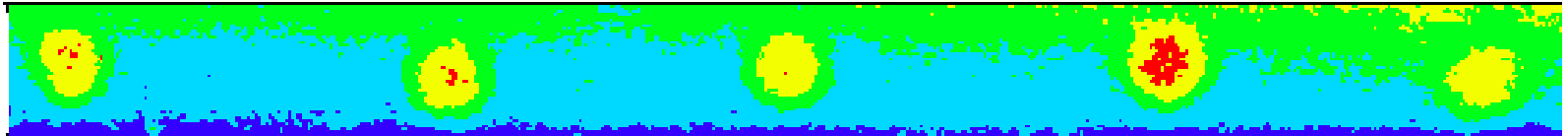


Pulse Phase Thermography

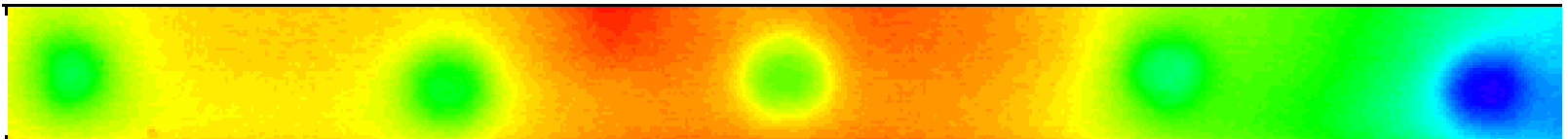


5 cold welds

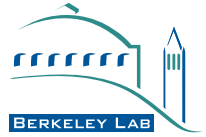
PPT maximum phase (strip c3):



PPT maximum amplitude (strip c3):



Conclusions



- Pulsed thermography provides good information about welding process
- To date not a reliable method to determine weld quality in galvanized steel
- Maximum phase and amplitude images good indicator but not fully understood
- Need to analyze and incorporate pulse strength into the analysis
- Several post-processing methods required